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PHYTOLITHS IN SOME AUSTRALIAN DUSTS

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Abstract

Phytoliths are important, if not abundant, constituents of dust in Australia. The common varieties are opal-phytoliths, but calcite-phytoliths and quartz-phytoliths have also been detected. The ubiquitous opal-phytoliths are often needle-like rods and hooks of microscopic size. They are derived from plants, soils, and the faeces of herbivorous animals, having been initially precipitated in plants from silica in solution. The shapes of many opal-phytoliths, their small size, and relatively low specific gravity, favour them becoming airborne. Thus, they are available in small quantities to be drawn into the human system, and to enter the moving parts of vehicles where they can cause wear, especially under very dusty conditions.

Introduction

Following the discovery that most of the small opaline bodies with varying shapes in Victorian soils are principally opal-phytoliths (Baker 1959a, b, c), samples of dusts from widely separated localities E. of 130° longitude in E. Australia were examined under a petrological microscope primarily to determine their contents of opal-phytoliths ('plant opal') and any other types of phytoliths that might be present. As a result of this examination calcite-phytoliths and quartz-phytoliths were detected for the first time in either dusts or soils.

Dust accumulated inside a building over a period of 11 years was also found to contain opal-phytoliths.

This study of dusts serves to indicate the extensive areal distribution of opal-phytoliths in the E. half of Australia. Opal-phytoliths are not only common in the soils and hence in the plants which generated them, but are also important components of both field and indoor dusts.

During the 1939-45 war, 16 samples of dusts from 12 widely separated localities in the E. half of Australia were examined by the author for the Research Branch, Engineering Section, Army Department, Commonwealth of Australia. The results of mineralogical determinations and particle counts showing grain size distribution in each dust were incorporated in Report T.I. 729A, M.G.O. Branch—Design Establishment, Army Department. Opaline bodies then detected were recorded as 'spicules'. Re-examination of the original slide mounts reveals that these spicules of opaline silica ($SiO_2.nH_2O$) are actually opal phytoliths ('plant opal') that were initially secreted as inorganic precipitates within plants. Other bodies of opaline silica are few in number, diatom frustules and silicisponge spicules being rare.

Sampling and Location of Dusts

The dusts were sampled by the Army Department in specially designed collectors during tests conducted in areas (see Fig. 1) where considerable quantities of dust were likely to enter the drivers' cabins, air-intake systems, wheel bearings, etc., of mechanized vehicles. The localities where dust samples were obtained are: Ouyen in the Mallee, N. Victoria; Bourke, New South Wales; Canberra, Australian Capital Territory; Mt. Isa, Winton, Charleville, Number 6A Bore—all in Queensland; Alice Springs, Barrow's Creek, Mataranka, Darwin, Adelaide R.—all in the Northern Territory.

One dust sample was taken at most localities, 3 separate samples were taken at Alice Springs, and 3 at Adelaide R. All were collected on moist filter papers mounted

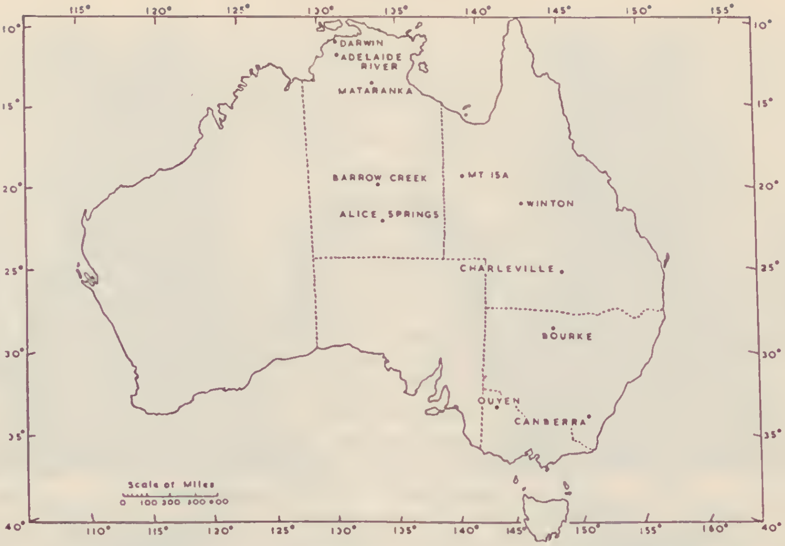

FIG. 1.—Sketch map of Australia showing locations where dust samples were obtained.

in sampling devices placed in one, sometimes in all three of the following positions: (a) inside the cabin, (b) under the bonnet or elsewhere under or upon the vehicle, and (c) on the edge of the track followed by the vehicles of a moving convoy. The convoy followed a circuit so planned as to take advantage of wind directions favourable to the movement of stirred-up dust relative to the positions of the collectors. Collectors (a) and (b) were placed in the rearmost vehicle of each convoy, this vehicle being generally obliterated from view by a dense pall of dust during the tests at most localities.

The dusts are of local derivation in each area, none was contaminated by dust particles carried from distant sources in the vehicles employed for the tests. It remains undetermined, however, whether a proportion was carried in to each area prior to the tests by natural agencies such as air currents concerned in soil erosion, or herbivorous animals that discharge considerable quantities of opal-phytoliths in their faeces. Any carried in by other vehicles are likely to be negligible.

The quantities of dust obtained on the filter papers were small in each test, but sufficient was recovered to make one microscope mount of each. Consequently, none was left for immersion tests in refractive index liquids. Permanent mounts were made in Canada balsam for grain-size counts and mineral-particle determinations. Owing to the fine particle size (mostly under 0·20 mm., with the greater proportion between 0·005 mm. and 0·15 mm.), each mount of the dusts contained approximately 15,000 particles. One or two mounts contained less because of coarser particle size and smaller initial quantities collected on the filter papers. A few contained 20,000 particles or more. These figures were estimated from the total number of particles counted in two typical fields of view, multiplied by half the total number of fields of view in the entire mount, magnifications of 360× being employed.

In addition to opal being present as phytoliths, diatoms and silicisponge spicules, a few fragments of opal are independent detrital or authigenic grains derived from soils.

Mineral Particles

The mineral particles of the dusts are largely angular in outline. All are of detrital origin, *sensu stricto*, even though some were evidently authigenic to the soils from which the dusts were derived.

Quartz, the principal mineral constituent in the dusts, reaches maximum abundance in the three size fractions: 0·05 mm., 0·10 mm. and 0·15 mm.

Other minerals present are: calcite; flakes of biotite and muscovite; fresh and partially altered cleavage fragments of felspar; crystals of zircon; grains of limonite, hematite, leucoxene, hornblende and tourmaline. Of lesser frequency are garnet, gypsum, apatite, augite, spinel, rutile, epidote, sphene, topaz, actinolite, black opaque iron oxides and undetermined clay minerals.

The hornblende appears in only a few dust samples, gypsum in even fewer, and the minerals listed as being of less frequent occurrence are sometimes absent from several of the dusts. Calcite is common to some dusts, rare in others, or occasionally absent. It occurs as granular aggregates and lenticular forms (flat rhombohedra with rounded outlines) in dusts from Bourke, Canberra, Ouyen, Alice Springs and Mataranka. Evidently its origin was largely authigenic in the topsoils from which the artificially stirred-up dusts were derived. Some granular aggregates of calcite have the same external forms as some of the opal-phytoliths, and, as such, can only have been developed in plants in a manner similar to that of opal-phytoliths, hence they are calcite-phytoliths ('plant calcite'). Comparable shapes in gypsum and apatite have not been observed in these dusts, although searched for.

Many of the mineral particles and some of the opal-phytoliths (e.g. Fig. 10, no. 33) are partially coated with limonite and/or hematite, more particularly in dusts from parts of Queensland and the Northern Territory. The striking red, pink and brown colours of these dusts are attributed to the frequency of these coatings on grains and to independent particles of earthy iron hydroxide.

The detrital mineral assemblages of the dusts from Bourke and Canberra are generally similar, but the dust from Bourke has rather fewer opal-phytoliths.

Organic Particles

Particles of organic matter are ubiquitous in the dusts. They consist of the more resistant fragments of plant tissues and fibres, and a few pollen grains and microspores. The smaller plant fragments, 0·01 mm. and under in size, are usually more common than detrital mineral fragments of similar dimensions, but larger plant fragments are less frequent than detrital mineral grains in the coarser size fractions (over 0·01 mm.). A few of the plant fragments still contain opal-phytoliths *in situ*.

Occasional fragments of insect remains were also observed.

Opal-phytoliths

The opal-phytoliths in the dusts are detrital. Originally released into soils as discrete bodies of various shapes (see Figs. 2 to 11) on destruction of the plants in which they were secreted, they became included in the dusts by winnowing-out from the surface of dry, loose topsoils as a result of turbulence created by convoys of moving vehicles used in sampling tests. They have the dimensions and specific gravity (approx. 2·15) to become airborne on agitation by air currents.

1. PROPORTIONS IN INDIVIDUAL FIELD DUSTS

Particle counts of the dusts were conducted to determine the proportions of phytoliths, diatoms and silicisponge spicules. Detrital mineral particles and organic particles were grouped together for the purposes of the particle counts. Calcite-phytoliths were too few and occurred in only one or two of the dusts, hence they do not enter into the particle counts; quartz-phytoliths were even rarer. The relative softness of calcite and its chemical instability under certain soil conditions, render it less susceptible to survival than opal-phytoliths. It has been rarely observed as phytoliths in plants. As a component of dusts, it does not merit serious consideration in relation to the problem of wear of moving parts of vehicles.

The proportions of particles revealed by the counts are listed in Table 1.

TABLE 1

Proportions of opaline silica bodies in some Australian dusts
(Percentages by particle count)

No.	Locality	Opal-phytoliths %	Diatoms %	Silici-sponge spicules %	Detrital minerals and organic matter %
1.	Ouyen, Vic.	0·3	pr.	n.o.	99·7
2.	Alice Springs, N.T.	0·3	pr.	n.o.	99·7
3.	Alice Springs, N.T.	0·4	pr.	n.o.	99·6
4.	Alice Springs, N.T.	1·2	0·1	n.o.	98·7
5.	Barrow's Creek, N.T.	1·9	0·1	n.o.	98·0
6.	Mataranka, N.T.	0·6	pr.	pr.	99·4
7.	Darwin, N.T.	0·7	pr.	n.o.	99·3
8.	Adelaide R., N.T.	2·5	0·1	pr.	97·4
9.	Adelaide R., N.T.	2·6	0·1	pr.	97·3
10.	Adelaide R., N.T.	2·8	0·1	pr.	97·1
11.	Mt. Isa, Q.	1·5	pr.	n.o.	98·5
12.	Number 6A Bore, Q.	1·9	0·2	pr.	97·9
13.	Winton, Q.	1·2	pr.	pr.	98·8
14.	Canberra, A.C.T.	1·0	pr.	n.o.	99·0
15.	Charleville, Q.	0·5	0·1	n.o.	99·4
16.	Bourke, N.S.W.	0·7	pr.	n.o.	99·3

KEY—n.o. = not observed in the slide mounts.
pr. = observed in slide mounts but not encountered in equally spaced micrometric traverses.

The positions of the dust collectors placed (a) within or upon the rearmost vehicle in moving convoys, or (b) near the testing circuit tracks at the various localities listed in Table 1 were as follows:

Nos. 1 and 4—inside the driver's cabin;
Nos. 12 and 16—on top of the cabin roof;
Nos. 2, 5 and 7—under the engine cover;
Nos. 3, 6, 8, 9, 11 and 13—2 ft. above the ground and 3 yds. from the testing circuit track; on the down-wind side of the moving convoys;
No. 14—below the radiator;
No. 15—under the chassis;
No. 10—on top of the tool-box in an M.G.K. machine-gun carrier.

Table 1 shows there are greater quantities of opal-phytoliths than opaline frustules of diatoms and opaline silicisponge spicules in all of the dusts. The increase of diatoms from Number 6A Bore is a reflection of proximity to bore water.

Among the dusts collected in 3 different positions for tests conducted at Alice Springs (Table 1, Nos. 2, 3 and 4), it is notable that the greatest percentage of opal-phytoliths was collected in the driver's cabin (Table 1, No. 4). Particle size studies revealed that this dust also contained coarser particles than those collected from (a) the side of the track on the down-wind side of the moving convoy and

(b) under the engine cover. Thus, coarser and more abundant opal-phytoliths, many of which are minute rods and needle-like, were carried into the driver's cabin.

The shapes of many of the opal-phytoliths and their relatively low specific gravity are conducive to stream-lining in air currents of the requisite strength. Their greater frequency in the driver's cabin is probably due to more complicated turbulence of dust-laden air currents, since the rearmost vehicle carrying the dust collectors had to pass through already turbulent dust-laden air stirred up by all other vehicles in the convoy.

The greatest percentages of opal-phytoliths occur in the dusts sampled at Adelaide R. The variety of shape types is illustrated by Figs. 5 to 8. Evidently the vegetation in this area has greater phytolith-generating propensities than in other areas where dust was sampled (cf. Table 1). The poorest assemblage for numbers and variety of shape types of opal-phytoliths is in the dust from Ouyen (Fig. 2, nos. 1 to 11).

2. Shapes and Sizes in Field Dusts

Opal-phytoliths in the dusts are best observed under a petrological microscope at magnifications of 505× and 755×, with the high-power condenser inserted and the illumination suitably reduced by means of the upper and lower diaphragms of

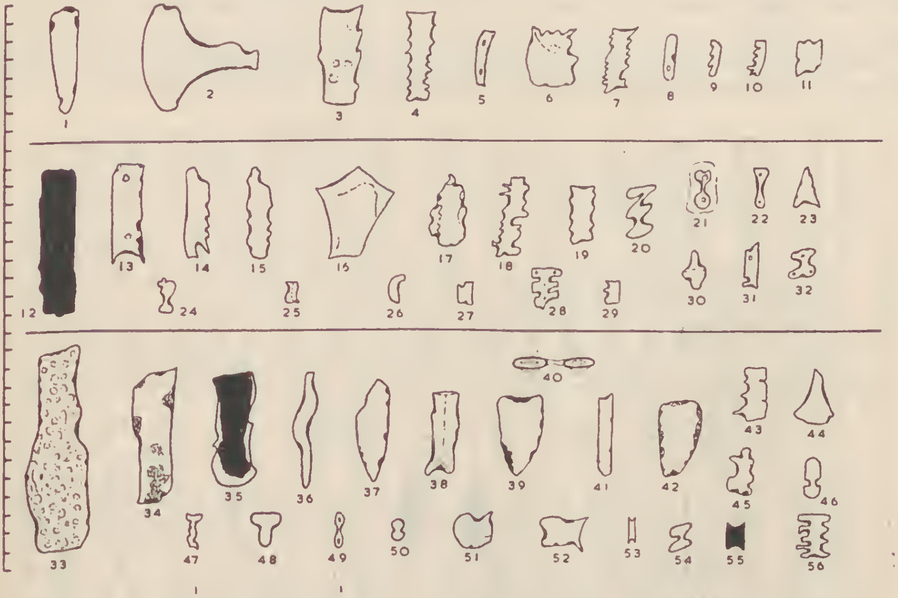

Fig. 2.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 11—from Ouyen, N. Vic. (Table 1, No. 1), in dust from a collector placed inside the driver's cabin of the rearmost vehicle in a moving convoy.
Nos. 12 to 32—from Alice Springs, N.T. (Table 1, No. 2), in dust from a collector placed under the engine cover of the rearmost vehicle in a moving convoy.
Nos. 33 to 56—from Alice Springs, N.T. (Table 1, No. 3), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles.
(Each scale division represents 0·010 mm.)

the sub-stage condenser system. Under these conditions, opal-phytoliths in Canada balsam permanent mounts are brought into contrast with other constituents of the dusts, since the refractive index of opal is well below that of the mounting medium, the quartz, and most plant fragment tissues.

The shapes and sizes of opal-phytoliths in the dusts (Figs. 2-11) are comparable with those in the silt- and sand-size fractions (0·005 mm. to 0·050 mm. grades) of soils (Baker 1959a, b); most of those illustrated have been observed also in various parts of living plants. Some large rod-shaped opal-phytoliths in soils less subjected to wind erosion, however, are not so much affected by attrition as some in the dusts, where several larger forms were fractured on becoming airborne during turbulent airflow. This may have occurred naturally or partly during the tests. Whichever the cause, it is likely that some of the better preserved larger opal-phytoliths were recently shed into soils from plants, because they are not coated with thin films of iron hydroxide like some fragments fractured from apparently earlier released opal-phytoliths, and since they reveal no evidence of corrosion in the soils.

The effects of fracturing have an important bearing upon the dust problem, because a greater number of smaller and more angular particles of a sharp-edged abrasive substance with a relative hardness of 5·5 to 6·5 are thereby created. Some can then be drawn into the human system by inhalation, others come into contact with moving metal surfaces of the vehicles, and with fragments of even harder, sometimes angular more abundant particles of quartz, they assist in undue wear of bearings, cylinders, etc.

Some of the smallest of the opal-phytoliths also become fractured, as evidenced by the more obvious examples such as isolated bulbous ends, 10-15 μ long, of dumb-

Fig. 3.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 79—from Alice Springs, N.T. (Table 1, No. 4), in dust from a collector placed inside the driver's cabin of the rearmost vehicle in a moving convoy.
Nos. 80 to 115—from Barrow's Creek, N.T. (Table 1, No. 5), in dust from a collector placed under the engine cover of the rearmost vehicle in a moving convoy.
(Each scale division represents 0·010 mm.)

bell-shaped forms. The original forms were dumbbells 20-25 μ long, and these became broken across slender waist regions which usually measure only 2-3 μ in thickness. Such types are well represented in the dust from Alice Springs.

The phytolith assemblages of these dusts from only a few feet above the ground, show a greater variety of shape types and a greater proportion of larger forms than those which become airborne and carried to higher levels, ultimately to be precipitated with rain and snow (cf. Baker 1959a, pp. 79-81).

ROD-SHAPED OPAL-PHYTOLITHS

The most common opal-phytoliths in the dusts are rod-shaped forms like those observed in soils. They vary from narrow forms 0·020 mm. long and 0·003 mm. wide in the Alice Springs dust (Fig. 3, no. 79), through broken forms 0·040 mm. long and 0·015 mm. wide in the Darwin dust, to more stumpy, complete rods 0·060 mm. long and 0·030 mm. wide (Fig. 10, no. 10) to 0·170 mm. long and 0·050 mm. wide (Fig. 7, no. 4).

Occasional needle-like rods are 0·250 mm. long and 0·008 mm. wide in dust from Winton (Fig. 10, no. 1). Others are thicker and measure 0·220 mm. by 0·030 mm. as in one of the Adelaide R. dust samples. One large rod 0·275 mm. long and 0·030 mm. wide in dust from Mt. Isa, has smooth, more or less parallel longer edges; a more slender rod 0·340 mm. by 0·020 mm. in dust from Adelaide R. has serrated longer edges.

Many rod-shaped forms with smooth edges generally have relatively straight, parallel sides (cf. Fig. 9, no. 1; Fig. 5, no. 8), but a few are curved (Fig. 5, no. 27) and sometimes tapered (Fig. 3, no. 4). The rods can be differentiated readily from

FIG. 4.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 43—from Mataranka, N.T. (Table 1, No. 6), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles.
Nos. 44 to 98—from Darwin, N.T. (Table 1, No. 7), in dust from a collector placed under the engine cover of the rearmost vehicle in a moving convoy.
(Each scale division represents 0·010 mm.)

silicisponge spicules because they are solid rods of opaline silica and lack the narrow axial canal so typical of many sponge spicules. No means has been found, however, to distinguish with certainty between broken sponge spicules and the silicified plant hairs with narrow central cavities; such forms are normally rare in dusts and soils.

Other types of rods have usually one, sometimes both of their longer edges embayed and crenulated (Fig. 3, nos. 1, 7, 80 and 81; Fig. 4, nos. 1 and 44; Fig. 11, no. 42). Others are sharply serrated (Fig. 2, no. 4; Fig. 3, no. 14; Fig. 4, no. 4; Fig. 5, nos. 6, 21, 24 and 31; Fig. 7, nos. 8, 52 and 55; Fig. 8, no. 6; Fig. 10, no. 30; and Fig. 11, nos. 12, 13 and 29). Some rods are spinose (Fig. 2, no. 18; Fig. 3, no. 93; Fig. 4, no. 56; Fig. 5, no. 5; Fig. 6, no. 67; Fig. 7, nos. 25-7; Fig. 8, no. 16; Fig. 9, no. 39; and Fig. 11, no. 43). A few resemble long wedges, they become flatter and thinner in one plane towards one end. One or two reveal knob-like outgrowths (Fig. 8, no. 5).

Only a small number of the embayed, crenulated, serrated and spinose rods show evidence of chemical corrosion (e.g. Fig. 2, nos. 33 and 34; Fig. 7, no. 29). The varied shapes and structures of the rods are thus largely attributable to primary development as such within certain types of plant cells of which they form complete and partial internal casts. All types of rods have now been observed *in situ* in various plant hosts, as well as in soils and dusts. Some of the rods are internal casts of cells with scalariform structure (e.g. Fig. 3, nos. 13 and 14; Fig. 5, no. 6; Fig. 6, no. 4; Fig. 7, no. 55; and Fig. 8, nos. 8 and 9).

Rod-like forms usually occur as separate entities in the dusts, as in soils, but a number are sometimes attached to thin plates of opal in dusts from Mt. Isa (Fig. 9, no. 10) and Winton (Fig. 10, no. 3). Minute, slender rods up to 20 in number and averaging 0·003 mm. long and 0·00015 mm. wide, accompanied by a few minute

FIG. 5.—Sketches of outline shapes of opal-phytoliths in some Australian dusts. Nos. 1 to 51—from Adelaide R., N.T. (Table 1, No. 8), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles. (Each scale division represents 0·010 mm.)

dumbbell-shaped opal-phytoliths embedded in plant fragments approximately 0·15 mm. long, occur in dust from Winton (Fig. 10, no. 2). In the same sample, a narrow curved rod with crenulate edges and measuring 0·040 mm. long and 0·003 mm. wide (Fig. 10, no. 4) occurs in a plant fragment 0·065 mm. long. In the centre of one piece of plant fibre in this dust is a narrow opal-phytolith rod 0·25 mm. long (Fig. 10, no. 1); another resembling it occurs in dust from Adelaide R. (Fig. 5, no. 4). Plant fragments in dust from Charleville sometimes contain opal-phytolith rods with crenulated edges, sometimes 'chunky' forms (e.g. Fig. 11, nos. 45 and 47) large enough to nearly fill the lumen of some plant cells. Others contain a mixture of irregular opal-phytoliths of nondescript shape, and ragged needle-like rods up to 0·100 mm. long. Elongated plant fibre fragments in dust from Adelaide R. contain up to 2 dozen opal-phytoliths; most are rods averaging 0·007 mm. long and 0·002 mm. wide, a few are dumbbell-shaped forms 0·005 mm. long. One plant fragment in dust from Adelaide R., consisting of an assemblage of partially silicified cells, was packed with opal-phytoliths, one to each cell.

Plant fragments with opal-phytoliths are more common in dusts from the northern parts of Australia, especially those from Adelaide R., Mt. Isa and Winton. They are also more frequent than hitherto observed in Victorian soils (cf. Baker 1959a, b).

HOOK-, SPINE- AND HAIR-LIKE OPAL-PHYTOLITHS

Some of the more slender, tapering forms (e.g. Fig. 3, no. 4) evidently represent opalized plant hairs. Other types are hook-like (Fig. 2, no. 44; Fig. 3, nos. 9, 39 and 91; Fig. 4, nos. 3, 59 and 69; Fig. 5, nos. 25 and 41; Fig. 6, no. 43; Fig. 7,

FIG. 6.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 62—from Adelaide R., N.T. (Table 1, No. 8), continuation of Fig. 5, nos. 1 to 51, but showing the smaller shape types.
Nos. 63 to 81—from Adelaide R., N.T. (Table 1, No. 9), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles.
(Each scale division represents 0·010 mm.)

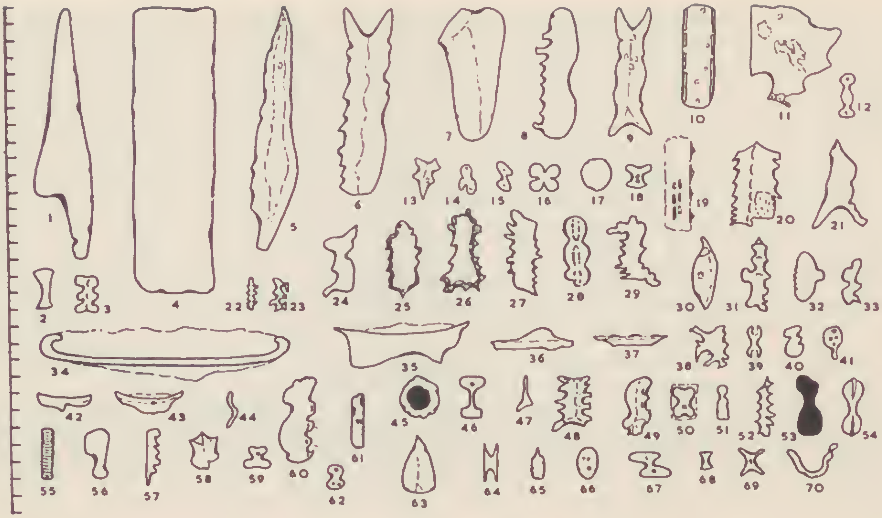

Fig. 7.—Sketches of outline shapes of opal-phytoliths in some Australian dusts. Nos. 1 to 70—from Adelaide R., N.T. (Table 1, No. 9), continuation of Fig. 6, nos. 63 to 81.
(Each scale division represents 0·010 mm.)

nos. 1 and 30; Fig. 8, no. 34; Fig. 9, nos. 2, 15, 17, 18 and 48; Fig. 10, nos. 6 and 18; and Fig. 11, nos. 8, 9, 14 and 55). Occasional forms are spine-like (Fig. 4, no. 24; Fig. 6, nos. 24 and 40; Fig. 7, no. 47; Fig. 8, nos. 29 and 33; Fig. 9, no. 42; and Fig. 11, nos. 15 and 44). Most of these types are undoubtedly from grasses and allied plants. They are commonly observed protruding from the epidermal cells of several living grasses and cereals, especially species that are harsh to the touch. One example (Fig. 11, no. 28) reveals a small needle-like tip of isotropic opal 0·015 mm. long and up to 0·003 mm. wide, set in anisotropic cellulose. One fragment of plant fibre in dust from Adelaide R. revealed small opalized hooks 0·007 mm. long, in addition to several minute rod-like forms arranged as in Fig. 7, no. 19.

Dumbbell-shaped Opal-phytoliths

Dumbbell-shaped opal-phytoliths are next in abundance to rod-like forms in many of the dusts. They are well represented at Alice Springs (Fig. 3, nos. 25-32 and 46-54), Barrow's Creek (Fig. 3, nos. 102-7), Mataranka (Fig. 4, nos. 57-8 and 87) and Adelaide R. (Fig. 5, nos. 1, 45-7; Fig. 6, nos. 7-19, 35, 38, 65 and 77; Fig. 7, nos. 12, 15, 46, 50, 62 and 67; and Fig. 8, nos. 18 and 38-57). They are less frequent in the other dusts and rare in the Mt. Isa, Charleville and Ouyen samples. The best arrays of dumbbell-shaped types occur in the Alice Springs and Adelaide R. dusts, and like many other small forms of opal-phytoliths, their outlines are often as well preserved as those *in situ* in plants. In fact, several are still linked together in pairs (Fig. 5, no. 47) or threes (Fig. 9, no. 45) in the dusts, sometimes isolated from plant tissue, sometimes still embedded in plant fragments. Others are linked end-to-end in rows of 8 individuals held in place by thin plates of opal representing cell-wall-linings, as in dust from Adelaide R. (Fig. 5, no. 1). A remarkable feature of connected dumbbell-shaped opal-phytoliths is the manner in which 3 different types of dumbbells in one particular row, regularly alternate. The example illustrated in Fig. 5, no. 1, reveals an alternation thus:

1–2–3–2–1–2–3–2

so that every 2nd form (2) is a dumbbell with a slightly thicker waist, while every 4th form (1) is a dumbbell with a more slender waist or (3) a dumbbell-like form with an additional swelling on one or both sides of the waist region. One plant fragment in dust from Adelaide R. revealed 16 dumbbell-shaped opal-phytoliths each 0·025 mm. long and 0·006 mm. wide. These occurred in strings of 4 in strands of plant fibre alternating with phytolith-free strands.

The small spots shown in some sketches of dumbbell-shaped opal-phytoliths (e.g. Fig. 2, nos. 22, 32 and 49; Fig. 3, nos. 30, 50, 102, 103 and 107; and in other figures) represent areas of attachment to other dumbbell-shaped forms or to cell walls that became internally lined with thin films of opal. These points of attachment are sometimes slightly broader flatter areas, sometimes minute pustule-like excrescences.

The smallest dumbbell-shaped forms in these dusts are only 0·005 mm. long (e.g. as in the Adelaide R. sample). Some dumbbells have evidently united by 'fusion' to produce multi-bulbous types (Fig. 5, no. 40). Others have a zig-zig appearance due to unequal growth in different directions (e.g. Fig. 2, no. 20, etc.).

An important feature of dumbbell-shaped forms is that the dumbbell-shaped outlines are only seen in plan aspects. Where possible to observe and measure in side aspects, they are generally plate-like to hourglass-shaped and only 0·005 mm. thick in forms that range up to 0·030 mm. long. Occasional dumbbell-shaped forms show complete but sometimes rather vague dumbbell-shaped outlines in plan aspect and variations in thickness are evident from refractive index effects. The result is that outlines are ghost-like in places but better defined where the opal is thicker

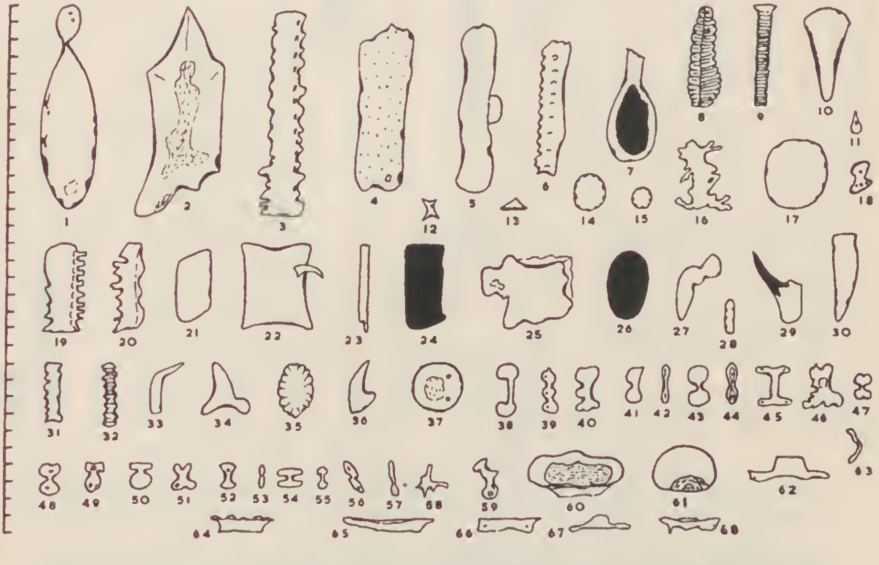

FIG. 8.—Sketches of outline shapes of opal-phytoliths in some Australian dusts. Nos. 1 to 68—from Adelaide R., N.T. (Table 1, No. 10), in dust from a collector placed on top of the tool-box in an M.G.K. machine-gun carrier. (Each scale division represents 0·010 mm.)

(e.g. as in Fig. 6, nos. 65 and 77). The poorly defined edges of such forms are under 1 μ thick. Other dumbbells are attached as single individuals to a thin plate of opaline silica that is evidently part of a cell-wall-lining (Fig. 7, no. 50).

The two bulbous ends of dumbbells are not always equally developed (e.g. Fig. 3, no. 29). The waist regions of some dumbbells are narrow and slender (Fig. 3, no. 97), others are much thicker and shorter (Fig. 3, no. 25). The distal regions of the bulbous ends are also variable in outline, some being smoothly curved (Fig. 3, no. 30), some flat, angular and occasionally notched (Fig. 4, no. 33), others rounded and notched (Fig. 3, no. 28) or completely different from one another (Fig. 3, no. 46). Other minor variations are shown in Figs. 2 to 11.

Complex Opal-phytoliths

A complex group of opal-phytoliths in which some of the outlines resemble those of clover leaves (Fig. 6, no. 63) is approximately 0·130 mm. long and 0·080 mm. wide. The phytoliths average 0·015 mm. across and are 3-lobed, 4-lobed and 5-lobed in plan aspect. They are plate-like, being only 0·003 mm. thick. By means of a minute point of attachment on each lobe of each phytolith, they are connected to a larger plate of opal which itself represents partially replaced cell-wall structures, parts of which are brought into focus at various depths by racking down the nose-piece of the microscope. This connecting plate of opal is therefore not merely a piece of cell-wall-lining, but represents portion of cell-wall structures replaced by opaline silica.

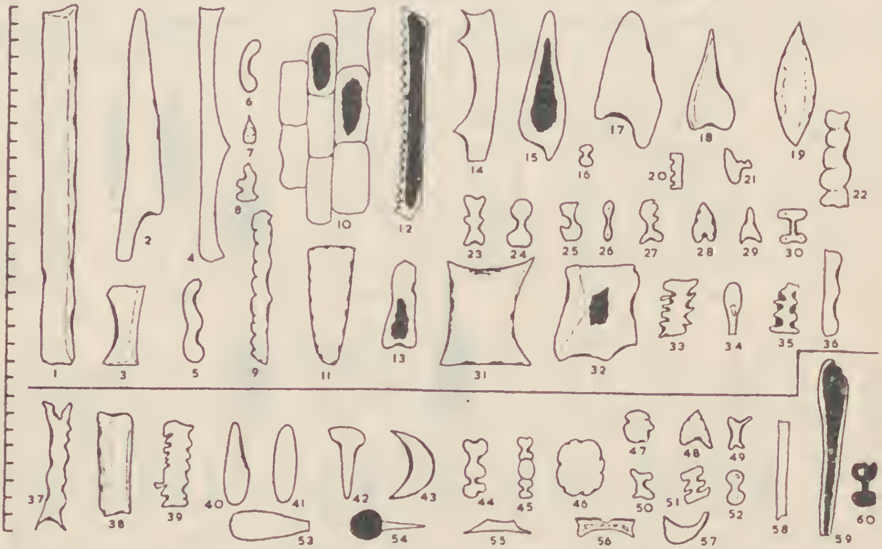

Fig. 9.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 36—from Mt. Isa, Q. (Table 1, No. 11), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles.
Nos. 37 to 60—from Number 6A Bore, Q. (Table 1, No. 12), in dust from a collector placed on top of the cabin roof of the rearmost vehicle in a moving convoy.
(Each scale division represents 0·010 mm.)

Berry-, Ball- and Barrel-like Opal-phytoliths

Berry-shaped and ball-like opal-phytoliths are not common in the dusts. A few occur in dusts from Alice Springs (Fig. 3, nos. 69 and 70), Adelaide R. (Fig. 6, nos. 34 and 70; Fig. 7, nos. 17 and 45; and Fig. 8, nos. 14 and 15), and Number 6A Bore (Fig. 9, no. 46). In the other dusts only one or two such forms have been detected, in some dusts none at all. Tiny round isotropic bodies down to 0·001 mm. in diameter occur in dust from Winton and less commonly in some of the other dusts. The smallest forms are possibly *Cocci*, but some of the larger forms up to 0·005 mm. across appear to have the sculptural elements typical of the much larger round opal-phytoliths. Barrel-shaped forms are rare; one example is illustrated from the Canberra dust (Fig. 11, no. 20), and one from Bourke (Fig. 11, no. 49).

Wedge-like and Lunate Opal-phytoliths

Rare wedge-like forms that are thicker and shorter than the wedge-like rod-shaped opal-phytoliths occur in dusts from Bourke (Fig. 11, no. 45), Mataranka (Fig. 4, no. 20) and Adelaide R. Some resemble the forms figured by Parry and Smithson (1958, p. 1550) from the bulliform cells of grasses. Lunate forms are rather uncommon, e.g. in dust from Number 6A Bore (Fig. 9, no. 43). They represent partial cell-wall-linings of cells with rounded ends.

Hat- and Boat-shaped Opal-phytoliths

Hat-shaped opal-phytoliths occur in small numbers and are invariably of small size in several of the dusts, e.g. from Alice Springs (Fig. 3, no. 16), Barrow's Creek (Fig. 3, no. 115) and Adelaide R. (Fig. 6, nos. 56 and 57; Fig. 7, no. 36; and Fig. 8, nos. 62 and 67).

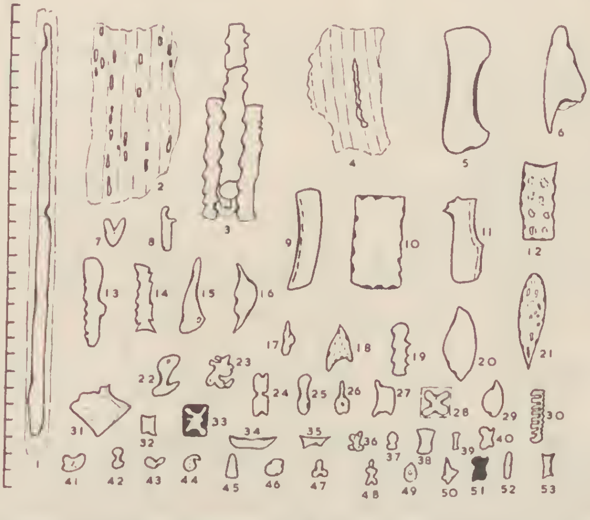

Fig. 10.—Sketches of outline shapes of opal-phytoliths in some Australian dusts. Nos. 1 to 53—from Winton, Q. (Table 1, No. 13), in dust from a collector placed 2 ft. above the ground and 3 yds. from the testing circuit track, on the down-wind side of a moving convoy of vehicles.
(Each scale division represents 0·010 mm.)

Boat-shaped opal-phytoliths of several types (e.g. Fig. 6, nos. 62, 78, 79 and 81; Fig. 7, nos. 35, 37 and 43; Fig. 8, nos. 64-6 and 68) are also infrequent in occurrence, being rather less common than the hat-shaped forms.

OTHER SHAPES OF OPAL-PHYTOLITHS

Hatchet-shaped (Fig. 5, no. 38), knucklebone-shaped (Fig. 10, no. 5), spindle-shaped (Fig. 9, no. 19, and Fig. 4, no. 43), club-like (Fig. 6, no. 1) and dish-like (Fig. 3, no. 76) examples of opal-phytoliths are uncommon. Oval-shaped forms (Fig. 4, no. 22) occur in small numbers in several, nondescript shapes (Figs. 2 to 11) are abundant in the majority of the dusts.

Twelve small opal-phytoliths measuring 0·006 mm. by 0·008 mm., and each with the shape shown in Fig. 10, no. 43, occur in a plant fragment measuring 0·07 mm. by 0·06 mm. in dust from Winton.

'Chunky' forms are common in some (e.g. Alice Springs and Adelaide R.), lens-shaped, spearhead-shaped, pear-shaped and flask-shaped forms are represented by one or two examples of each in a few of the dusts.

CELL-WALL-LININGS

Thin, plate-like forms with peripheral ridges (Fig. 4, no. 54) are cell-wall-linings of opaline silica representing partial internal casts of plant cells. The peripheral ridges are parts of the wall-linings normal to the plates carrying them, and sometimes show thickening along the angles of cell-wall junctions. Occasional 'angle-pieces' of opal are portions of this type of internal cast, and have broken away from

FIG. 11.—Sketches of outline shapes of opal-phytoliths in some Australian dusts.
Nos. 1 to 28—from Canberra, A.C.T. (Table 1, No. 14), in dust from a collector placed below the radiator of the rearmost vehicle in a moving convoy.
Nos. 29 to 39—from Charleville, Q. (Table 1, No. 15), in dust from a collector placed under the chassis of the rearmost vehicle in a moving convoy.
Nos. 40 to 56—from Bourke, N.S.W. (Table 1, No. 16), in dust from a collector placed on top of the cabin roof of the rearmost vehicle in a moving convoy.
(Each scale division represents 0·010 mm.)

the thinner films of opal that lined the internal surfaces of cell walls. Examples of this type have been detected in dust from Adelaide R. Thin plates with irregular outlines (Fig. 2, no. 16, and Fig. 7, no. 11) were broken away from thin films lining the internal walls of cells having flat inner surfaces. They sometimes possess thickened areas resembling irregular, low ridges. Other plates of opaline silica reveal distinct patterns of the cell-wall structures (e.g. Fig. 6, no. 66). These are sometimes quite complex.

Replacement Types of Opal-phytoliths

Cuticle replacements that preserve the anticlinal structures of the outer epidermal cells of such plants as the grasses (cf. Baker 1959a, pp. 73, 75, 76; b, pp. 91, 94; c) are represented by occasional fragments in some dusts (e.g. Fig. 3, no. 11, and Fig. 9, no. 4). They provide support for the theory that the process of silicification in living plants is not merely an infilling of the lumen of cells by plant opal, but that minor amounts of replacement of cuticular structures and cell-wall structures can take place while plants are still alive, thus indicating that partial auto-silicification by a plant is possible. This occurs mainly during late stages of growth (cf. Baker 1959c).

3. Variability of the Opal

Apart from the many shape variations and a small range in size of the opal-phytoliths (features that are largely controlled by the variations in shape and size of plant cells), the opal constituting the different varieties of shapes is itself liable to vary slightly, even within one and the same opal-phytolith. Varying Becke Line effects indicate small variations in the refractive index of the opal and reveal a layered structure in some types, more especially hook-like and spine-like varieties that partially protrude from the outer epidermal cells of some types of grasses and allied plants. These minor variations in refractive index from place to place in an opal-phytolith, reflect a small variability in the water content of the opal.

Colour variations are evident among the opal-phytoliths in the dusts; some have already been noted for examples examined from soils (Baker 1959a, p. 69). Variation in colour, however, has not yet been detected for opal-phytoliths still embedded in living plants. Whereas a bulk concentrate of opal-phytoliths prepared by plant digestion is usually pure white in colour, individual opal-phytoliths examined under the microscope from dusts and soils, show a range from colourless (usually with a very faint pinkish tinge), through grey and brown to almost opaque black. Colourless varieties are in the majority and are transparent like the hyalite variety of opal. Some are translucent to sub-translucent and show milky opalescence (e.g. that shown by Fig. 8, no. 5) of varying degrees of intensity, ranging from a faint milkiness to almost opaque greyish-white. Pale brown, yellowish-brown, mauve-brown and greyish-brown to opaque black opal-phytoliths are much fewer in number.

One rod-shaped opal-phytolith in dust from Adelaide R. revealed an opaque brownish-black core surrounded by a translucent colourless zone followed by an outer transparent zone with a pale pinkish tint. Darker coloured opal-phytoliths are sometimes black in both transmitted and reflected light, but those that have pale brown colours in transmitted light are usually light grey to white in reflected light. As revealed from an inspection of Figs. 2 to 11, opal-phytoliths of many and varied shapes can be dark coloured to opaque.

Among the dark coloured opal-phytoliths illustrated in Figs. 2 to 11, the only examples with external discolorations are those shown by Fig. 9, nos. 10 and 35, and Fig. 10, no. 33. The discolorations are due to thin coatings of iron-bearing minerals such as limonite, secondarily deposited on the phytoliths after release into the soils. Thin coats of secondary calcium carbonate have also been detected on a few opal-phytoliths in dust from Ouyen, but these have little effect upon colour. Only a few opal-phytoliths are black throughout (e.g. Fig. 2, no. 12; Fig. 4, nos. 61, 84 and 88; Fig. 6, no. 67; Fig. 7, no. 53; Fig. 8, nos. 24 and 26; Fig. 9, no. 60; Fig. 10, no. 51; and Fig. 11, no. 2). In most opaque forms, only central regions are opaque greyish-white, opaque brownish or opaque black, their outer zones being usually colourless and sub-translucent to transparent, although the outer zones of a few are sometimes mauve-brown.

The substances responsible for colouring opal-phytoliths have not been resolved under the highest magnifications of the polarizing microscope. Some 'milky' examples in dust from Alice Springs have two or three minute gas bubbles approximately 0·0005 mm. in diameter. A spearhead-shaped form in dust from Winton (Fig. 10, no. 21) has several bubbles of similar size. This is unusual for phytoliths generally, but the presence of detectable bubbles of measurable size may indicate that the milky appearance of some opal-phytoliths could be due to numerous bubbles of sub-microscopic dimensions.

The full significance of the coloured opal-phytoliths has not yet been determined. They represent the solid end products of siliceous precipitates from solutions taken up by plants from soils. Before attaining the solid amorphous state, they evidently pass through a gel phase. Since silica gel is noted for its absorptive capacity of trace elements, opal-phytoliths are to be suspected as the principal sites of trace element excess accumulations in plants.

Variations in the degree of corrosion of opal-phytoliths in the dusts are not easily detected. Most examples are in a similar state of preservation as those in living plants, and were evidently shed from their hosts only recently. Some, however, have been fractured and some broken into fragments. A small number is of greater antiquity because some opal-phytoliths show minute etch pits that impart a roughened appearance to their surfaces (e.g. Fig. 2, no. 33; Fig. 3, nos. 3 and 113; Fig. 4, no. 47; and Fig. 10, no. 18).

4. Occurrence in Indoor Dust

Opal-phytoliths in the smaller size range can become airborne for long periods just as readily as some of the other fine-grained particles of all sorts of matter in dusts. This is proved by their occurrence under field conditions, e.g. as in 'red rain' and 'red snow' residues (Baker 1959a, pp. 79-81). They may remain suspended for much shorter periods in artificially created dusts such as those under discussion. It then becomes pertinent to the question to determine whether they also occur in indoor dusts. With this in mind, a dark grey to nearly black coloured dust that accumulated over a period of 11 years on top of a fuse-box in a laboratory office room having two S.-facing windows surmounted with narrow wire-mesh covered air vents, was examined in clove oil ($n = 1{\cdot}53$) mounts. A count of 2,500 dust particles under a petrological research microscope at magnifications of 505×, revealed approximately 0·5% of opal-phytoliths. The majority were colourless and a few were 'milky' to opaque brownish in colour.

The range of shape types is:

(i) Slender rods averaging 0·05 mm. long and 0·005 mm. wide and up to a maximum of 0·100 mm. long and 0·010 mm. wide; some have straight relatively smooth longer edges, others have crenulated, spinose or serrated edges.

(ii) Various types of dumbbells similar to many in the field dusts (Figs. 2 to 11); their range in length is from 0·025 mm. down to 0·006 mm.

(iii) Hat-shaped forms 0·025 mm. long.
(iv) Boat-shaped forms 0·025 mm. long.
(v) Heart-shaped forms 0·025 mm. long.
(vi) Flask-shaped forms 0·030 mm. long, some of which could be original dumbbell-shaped forms broken across slender waist regions.
(vii) Spearhead-shaped forms 0·025 mm. to 0·030 mm. long.
(viii) Small, rectangular tabular forms 0·04 mm. long and approximately 0·003 mm. to 0·005 mm. thick.
(ix) Small hook-like forms 0·020 mm. across, derived from the outer epidermal cells of plants that secrete such forms.
(x) Oval-shaped forms 0·030 mm. long and 0·020 mm. wide.
(xi) Round, berry-like forms 0·020 mm. across.
(xii) Nondescript forms 0·025 mm. across.
(xiii) Angular fragments 0·020 mm. to 0·025 mm. across, broken by attrition from larger opal-phytoliths.

Among the many other constituents in this dust are:

(a) Soot particles with irregular tear-shaped and spherular forms; these are non-magnetic and consist principally of carbon.
(b) Fibres of cloth, etc.
(c) Fragments of lignin and cellulose.
(d) Occasional diatom frustules.
(e) One silicisponge spicule fragment (showing axial canal).
(f) Black magnetic bodies of spherular shape, sometimes largely metallic, often glassy and then referred to as 'slag-bombs' or 'smoke-bombs'. They are derived as fly-ash from the smoke-stacks of railway engines, steamships and factories; all are approximately 0·020 mm. in diameter.
(g) Irregular rusty magnetic particles of steel and iron, 0·020 mm. in size and under.
(h) Pollen grains.
(i) Bacteria (*Bacilli* and *Cocci*).
(j) A number of mineral fragments including angular quartz, small broken prisms of tourmaline, small grains of limonite, rare minute crystals of calcite, prismatic fracture fragments of augite, and several other undetermined fragments; these are mainly 0·025 mm. in size
(k) Angular fragments of the finest grades of carborundum powder used for grinding and dressing mineral and rock surfaces in the preparation room of the laboratory.
(l) Occasional chitinous fragments, etc., of insect remains.

Quartz-phytoliths

A dumbbell-shaped particle of quartz 0·030 mm. long in dust from Adelaide R. is regarded as a phytolith. Its shape and size are commensurate with those of opal-phytoliths, and it is the most suggestive among several quartz particles that appear to have affinities with phytoliths. Although not yet observed by the author in living plants nor in plant fragments in dusts, crystalline silica with $n =$ over 1·5 has been reported in timbers (Amos 1952). Hence, quartz-phytoliths must occur in plants. They are most likely to occur in plants of considerable longevity, such as trees. None has been observed in shorter-lived plants such as the grasses, many specimens of which have been investigated for their phytolith contents, and which are known to secrete numerous solid opaline bodies (as phytoliths) within the compass of one season's growth. It has not been determined whether quartz-phytoliths are precipitated directly as such within a plant, or whether they result from dehydration of the amorphous silica (constituting the opal-phytoliths) with the passage of time, either in the plant host or later after shedding into the soil, for examples have been observed only in dusts or soils. No transition phases have been detected that would indicate the transformation of opaline silica (amorphous) to chalcedony (cryptocrystalline plus amorphous silica). Once released into soils (or dusts) the chances of recognizing particles of chalcedony as of phytolithic origin are remote, unless their shapes are preserved, and chalcedony-phytoliths have not yet been found in plants.

Calcite-phytoliths

In dust from Mataranka, a few rod-shaped forms with crenulated edges and others with serrated edges (cf. Fig. 2, no. 4; Fig. 3, nos. 6 and 94; and Fig. 7, no. 9) are the same size and shape as some opal-phytoliths, but they consist of microgranular aggregates of calcite. Calcite-phytoliths with these shapes have yet to be detected *in situ* in Australian plants. Although $CaCO_3$ is well known as a constituent of the cystoliths of *Ficus macrophylla*, it does not have the shapes of the rods in the Mataranka dust, where they are more like the shapes of those generated as opal-phytoliths in grasses. The existence of 'plant calcite' being already established, calcite-phytoliths are to be expected, but their chance of survival in soils after release from plants is not likely to equal that of opal-phytoliths unless special conditions prevail.

Of interest to the question of the existence of other types of calcite-phytoliths than those already observed, is the occurrence in dust from Bourke of 'seed' calcite grains which are approximately the same size as seed gypsum grains. They are flat, obtuse rhombohedra with rounded solid angles, and it is not yet certain whether they are authigenic to the topsoil from which the dust was derived, or whether they also are calcite-phytoliths. Unlike opal-phytoliths, none of this particular type has been observed embedded in plant fragments constituting part of the dusts, and likely plant hosts from this area have not been examined for their phytolith contents. One 'seed' calcite grain was attached to an opal-phytolith, but there is no conclusive evidence to prove whether cementation together occurred in a plant or in the soil.

Conclusions

The occurrence of phytoliths in small but nevertheless significant quantities in all of the dusts collected from several widely spaced localities in the E. half of Australia, indicates the extensive nature of their distribution. In fact, taken in conjunction with their recorded occurrence from a number of other environments (Baker 1959a, b, c), one comes to realize that even if other types of phytoliths are relatively rare, the opal-phytoliths are ubiquitous in nature. They are widespread throughout the regolith portion of the lithosphere, and occur in lesser quantities in the lower layers of the atmosphere and in parts of the hydrosphere. They are now known to occur in varying abundance in (i) a number of Victorian soils (Baker 1959a, b); (ii) low-level dusts such as those discussed herein; (iii) higher-level dusts as evidenced by their occurrence in 'red rain' and 'red snow' residues (Baker 1959a) collected at various times in Victoria since the turn of the last century; (iv) tap-water (Baker 1959a), and hence are to be expected in reservoirs, dams, streams and lakes; (v) many varieties of indigenous and introduced plants in Victoria; (vi) the faeces of herbivorous animals; and (vii) indoor dusts. Fossil examples (Baker 1959c) have been observed in such sediments as diatomaceous earth, diatomaceous silty clay, calcareous-kaolinitic clay and carbonaceous clay of various ages in the Tertiary and Quaternary periods in Victoria. Opal-phytoliths are known from present-day soils and living plants in other parts of the world and hence have wide lateral distribution. The fossil examples prove that they are also of some considerable antiquity and that the process of phytolith-generation has been going on for several millions of years.

In the several environments where they have been investigated in some detail, particle counts reveal that opal-phytoliths constitute an average of 0·9% of soils (17 Victorian soils examined), 1·2% of artificially generated dusts (12 Australian field dusts examined), and 0·7% of naturally generated higher altitude dusts that were ultimately precipitated as 'red rain' or 'red snow' (4 Victorian 'red rain' residues and 'red snow' residues examined). Their proportions in indoor dust (0·5%—for one example only) are a little below those of higher altitude dusts. The ranges in the proportions by count are 0·06% to 2·6% for soils, and 0·3% to 2·8% for artificially generated dusts.

Under certain circumstances, dusts can therefore contain a significant proportion of sharp, needle-like, hook-like and granular bodies of opal. These are relatively hard and not easily soluble normally. Moreover, they are of microscopic dimensions. They can be drawn into the human system by inhalation of dust. Others are swallowed in small quantities with drinking water and with certain plant foods. The majority of those swallowed probably pass through the system and are discharged with the faeces. The rate of intake by humans, however, is relatively insignificant compared with the rate of intake by herbivorous animals. Sheep, cattle, horses, rabbits and Australian native species must ingest thousands of tons of opal-phytoliths per annum, and return the majority to the soil via their faeces. Many more thousands of tons of silica in solution, in the gel state and already precipitated as opal-phytoliths, lie temporarily locked up above ground in the aerial portions of plants.

Because of their nature and abundance, the opal-phytoliths are also significant in being a possible means whereby trace elements may be fixed.

The biochemical and biophysical processes that control the precipitation of amorphous silica ('plant opal') in various plant cells, and mould them into the numerous shape types, have yet to be elaborated. The shape and size of opal-phytoliths that completely fill the lumen of plant cells are determined by the limits of the internal walls of the cells. The characteristics of cell-wall-linings are also determined by cell shape, and their incompleteness is evidently a consequence of paucity in supply of inorganic matter from place to place in the plant structures where such substances are normally precipitated. The shape of opaline replacements of cuticle in grasses and allied plants is largely controlled and determined by the anticlinal nature of the outer walls of the epidermal cells.

The fact that complex groups of plant cells, sometimes including even stomatal cell structures, are preserved in detail by opaline silica in such plants as *Avena sativa* and species of *Poa*, indicates that actual replacement of cell walls can occur in addition to the more normal filling in of the lumen of cells to form internal casts of plant cells. The physical and chemical controls determining the generation of opal-phytoliths that only partially infill the lumen of plant cells, are not yet clearly revealed. The formation of small opal-phytoliths with dumbbell shapes that are regular in plan aspect, but plate-like and hourglass-like in side aspect, calls for an ordered type of deposition of amorphous silica under strictly controlled conditions, especially when remarkable alternations such as those evident from Fig. 5, no. 1, are taken into account.

The minor development of calcite-phytoliths compared with the ubiquitous opal-phytoliths, indicates either limited generation by lime-loving plants, or enforced precipitation of calcium carbonate in other plants growing on lime-rich soils. The general processes of precipitation and growth of calcite-phytoliths to conform with the internal shapes of plant cells, are likely to be comparable with the processes producing opal-phytoliths.

The presence of small numbers of birefringent (crystalline) silica phytoliths compared with the great abundance of isotropic (amorphous) silica phytoliths in the wood of trees, and the fact that birefringent silica has not been observed in grasses, reeds, sedges, etc., could explain the shortage of quartz-phytoliths in dusts and soils generally. Furthermore, quartz-phytoliths are not likely to be readily recognized in soils among the abundant quartz grains of different origin. It also suggests that the time factor may be important in determining whether quartz-phytoliths can be precipitated as such in plants of greater longevity, or whether they were only formed by gradual dehydration of amorphous silica precipitated initially as opal-phytoliths. In grasses and allied shorter-lived plants, the cycle of processes involving the absorption of silica-bearing solutions and the ultimate precipitation of opal-phytoliths from a gel phase, is completed within the compass of one season's growth. Because quartz-phytoliths do not appear in such plants, the indication is that crystalline silica is not precipitated as such within their cells. In trees that live for some hundreds of years, however, dehydration of amorphous silica with the passage of time, appears a more likely explanation for the occurrence in them of the much less frequent quartz-phytoliths. The reported occurrence of crystalline silica in timbers (Amos 1952) lends support to this hypothesis, and shows that the process does not have to be explained as an event subsequent to the release of opal-phytoliths into soils. The evidence accrued so far, favours the idea that silica secreted by all types of plants with siliceous phytolith-generating propensities, is precipitated initially as opal. This accounts for its ubiquity.

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